ELLIPTICAL CORE SUPPORT AND PLUG FOR A TURBINE BUCKET

BACKGROUND OF THE INVENTION

[0001] This invention relates to the manufacture of turbine buckets and specifically, to the configuration of cores and core supports used in casting the turbine bucket.

[0002] In casting of a turbine bucket, tangential core supports are often used, usually within the shank pocket region of the shell die to prevent core movement relative to the wax die during wax injection operation. Conventional core supports are usually configured as pins of circular cross-section.

[0003] Core support pins are connected to the core at a certain radial locations, for example, at the base or radially inward portion of what eventually will become an internal serpentine cooling passage. To ease the core manufacturing, a certain draft or taper is applied to the cylindrical surface of each pin along the die pull direction.

[0004] The core support pins create exit holes in the cast bucket, the shape and dimensions of which are determined by the core support pins. These core support exit holes must be closed with a core plug having the same cross-sectional shape as the core support pin, during a post-casting operation, typically a brazing operation.

[0005] The disadvantage of the circular core support pin is that it causes relatively high Kt stresses at the internal core blend and the external fillet region, at the nine and three o'clock positions of the circular support pin and the pin hole bosses. In addition, for plugs with certain preferred material orientation such as single crystal or directionally solidified alloy, the orientation needs to be identified and marked on the plug to match the main body material orientation, and certain measures need to be taken to prevent the plug from rotation during the installation of the pin in the exit hole.

BRIEF DESCRIPTION OF THE INVENTION

[0006] This invention discloses a uniquely shaped core support and plug. Specifically, in accordance with the exemplary embodiment, this invention provides an elliptical cross-sectional shape for the core support pin, core exit hole in the bucket, and core exit plug to reduce the Kt stresses at the internal blend or fillet of the core exit in the cast bucket, to thereby increase core producibility, and to provide a fool-proof installation if the plug needs to be oriented along a preferred direction, such as certain material orientation. The invention is also applicable to any other situation where an exit hole is created in any location in the bucket that requires subsequent closure with a plug.

[0007] Thus, in accordance with one aspect, the invention relates to a core for a shell die used in casting a turbine bucket, the core comprising an

elongated body shaped to create internal cooling passages in the bucket, the elongated body formed with at least one core support pin extending transversely of the elongated body and adapted to fix the core inside the shell die, the core support pin having an elliptical shape in cross-section.

[0008] In another aspect, the invention relates to a shell die and core for use in casting turbine buckets wherein the shell die is provided with a plurality of core support bosses having core support pin holes therein and wherein the core comprises an elongated body having a corresponding plurality of core support pins adapted to be received in the core support pin holes, the core support pins having elliptical cross-sectional shapes and the core support pin holes having substantially identical elliptical shapes.

[0009] In still another aspect, the invention relates to a cast turbine bucket having at least one exit hole created therein during casting, the at least one exit hole having an elliptical cross-sectional shape and an elliptical plug closing the at least one exit hole.

[0010] The invention will now be described in connection with the drawing figures identified below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIGURE 1 is a side elevation of a shell die used in the manufacture of a turbine bucket;

[0012] FIGURE 2 is a side elevation of a core adapted for mounting within the shell die of Figure 1;

[0013] FIGURE 3 is a partial perspective of a core support pin taken from the core shown in Figure 2;

[0014] FIGURE 4 is a partial perspective of the core support exit hole and plug in a cast turbine bucket;

[0015] FIGURE 5 is a partial perspective of a core support pin in accordance with an exemplary embodiment of this invention;

[0016] FIGURE 6 is a partial perspective of a core support exit hole in a cast turbine bucket and plug in accordance with an exemplary embodiment of this invention; and

[0017] FIGURE 7 is a cross section of a core support pin in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0018] With reference to Figures 1-4, a portion of a shell die 10 used in casting turbine buckets includes an airfoil portion 12, a shank pocket portion 14 and a mounting portion 16. The shank pocket portion 14 is provided with a plurality (three in this case) of core support bosses 18, 20 and 22 that depend from the underside of bucket platform 30, and that include respective support holes 24, 26, 28, respectively, and

[0019] Figure 2 illustrates a ceramic core 32 for use with the shell die 10. The core is typically mounted in the die 10, such that during the casting process, the core elements 34, 36, 38, 40, 42, 44, 46, etc. will define a serpentine cooling circuit within the interior of the bucket.

[0020] Core support pins 48, 50 and 52 extend transversely of the core and are used to fix the core within the die. These support pins are circular in cross-section and are received within the circular holes 24, 26, 28, respectively, formed in the bosses 18, 20 and 22. When the core 32 is removed after casting, the core support pins will leave exit holes (one shown at 54 in Figure 4) in the passage walls that need to be plugged. The plug 56, of similar circular cross-section, is brazed within the hole, sealing the latter and preventing leakage of cooling media.

[0021] With reference now to Figures 5-8, this invention provides a ceramic core 58 that is similar to core 32 except that the cylindrical core support pins 60 have an elliptical cross-section. The core support pin 60 is blended with the core main body 62 with a designed fillet 64, with a predetermined draft (or taper) applied to the core support pin along its length to ease the removal of core from the die. Based on elasticity analysis for an elliptical hole in a plate, the stress concentration is as follows for a load applied parallel to the major axis of the elliptical hole (in a bucket, this means the major axis of the elliptical core should be along the radial direction, i.e., in the centrifugal load direction):

$$Kt=1+2\ b/a \qquad (1)$$

where, a is the major axis radius of the elliptical hole and b is the minor radius of the elliptical hole (b<a).

[0022] From (1), one may see that the stress concentration becomes maximum for a circular-shaped hole (Kt=3) since we require the major axis be along the radial direction. Kt reduces proportionally with the elliptical ratio b/a. This can be used as a means to reduce the concentrated stress at the internal blend or fillet 64 where core support pin 60 connects with the main core body, and where the maximum stress occurs.

[0023] Based on elementary mechanics (e.g. Formulats for Stress and Strain by Roark and Young, McGraw-Hill, Inc.), the moment of inertia, Ic, of an elliptical cross-section about the minor axis is:

$$I_c = \frac{A^2}{4\pi}\left(\frac{a}{b}\right) \qquad (2)$$

where A is the cross-sectional area of the core support.

[0024] Therefore, for a constant cross-sectional area A, the bending cross-sectional stiffness of the core increases proportionally with a/b, thus increasing the core support stiffness and significantly reducing the likelihood of breakage of core support. This has been demonstrated through casting trials.

[0025] Figure 7 illustrates a correspondingly shaped hole 66 in a core support boss 68 within the shell die 70.

[0026] Due to the fact that the differentiation between the radial direction and transverse direction by geometry itself, there is only one way a corresponding elliptical plug 72 can be inserted into the exit hole 74 in the bucket 76 for brazing. Thus, the invention provides a fool-proof mechanism for avoiding operational errors where a preferred orientation between the plug and the bucket is required. The invention also eliminates the previously required marking operation.

[0027] The above described elliptical shape for exit holes and plugs is equally applicable to any situation in which an exit hole is created in the bucket, i.e., it is not limited to core support pins, and where the exit hole is subsequently plugged.

[0028] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.